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TECHNICAL MEMORANDUM

M65-3-1

UNITED STATES ARMY

FRANKFORD ARSENAL

MANUFACTURE OF URANIUM-8.5% MOLYBDENUM BALLS

by

R. V. LONDON
R. E. EDELMAN

July 1964

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DA Project 5S96-10-001

REPORT M65-3-1

PHILADELPHIA, PA. 19137

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FRANKFORD ARSENAL
Philadelphia, Pa. 19137

Technical Memorandum M65-3-1
July 1964
OCMS Code 5520.22.46804.03
DA Project 5S96-10-001

MANUFACTURE OF URANIUM-8.5% MOLYBDENUM BALLS

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ABSTRACT

In an effort to meet increasing demands by the army for components fabricated from dense materials (such as an 0.20 in. diameter ball weighing 20 ± 1 gr), a study was made to find suitable material and methods of processing. Of the two materials (uranium- and tungsten-based alloys) having the necessary density, an uranium-8.5% molybdenum alloy was chosen because of its combination of strength and ductility.

The problem of fabricating a smooth wire, free from kinks and surface imperfections, was undertaken at Frankford Arsenal, and the various phases of the process - casting, heat treating, forging, rolling, annealing, swaging, and testing - are described.

A feasibility study to determine techniques for manufacturing production quantities of uranium balls was undertaken by the contractor, using the cold heading technique and then grinding the rough balls to size, using standard production equipment. The methods of pressing the material, rill filing, and tumbling are described in the Appendix.

TABLE OF CONTENTS

INTRODUCTION

There has been an increasing demand by the Army for components fabricated from dense materials. One such component was a ball, approximately 0.20 inch in diameter, weighing 20 ± 1 gr. Two materials, uranium- and tungsten-based alloys, would have the necessary density to meet these requirements. An uranium-8.5% molybdenum alloy was chosen because of its combination of strength and ductility.

Since only limited data are available on the fabrication of uranium parts, several questions arose concerning the use of this metal in this particular application:

1. In what form should the uranium be prior to the ball-making process?

2. In what manner should the balls be made? i.e., cold heading or hot heading?

3. In what manner should the balls be finished?

4. Could the process used to make the initial quantities be scaled up to make production quantities?

After studying all the problems involved, it was decided to make the initial attempts on standard production equipment. Once this decision was made, the other three questions were automatically answered.

The production equipment used the cold heading technique which, in turn, required the feed stock to be smooth wire. After cold heading, the rough balls would then be ground to size, using production ball-grinding equipment. Thus, the initial problem faced by Frankford Arsenal was the fabrication of smooth wire, free from kinks and surface imperfections.

This report is concerned with the fabrication of uranium-8.5% molybdenum alloy wire at Frankford Arsenal. The Appendix is the contractor's report of his method of manufacturing 20-grain balls, using the Frankford Arsenal wire.

WIRE FABRICATION

Casting

Bars, 2-1/2 inches in diameter and 12 inches long, were cast in a vacuum furnace (schematically shown in Figure 1). Machined graphite,

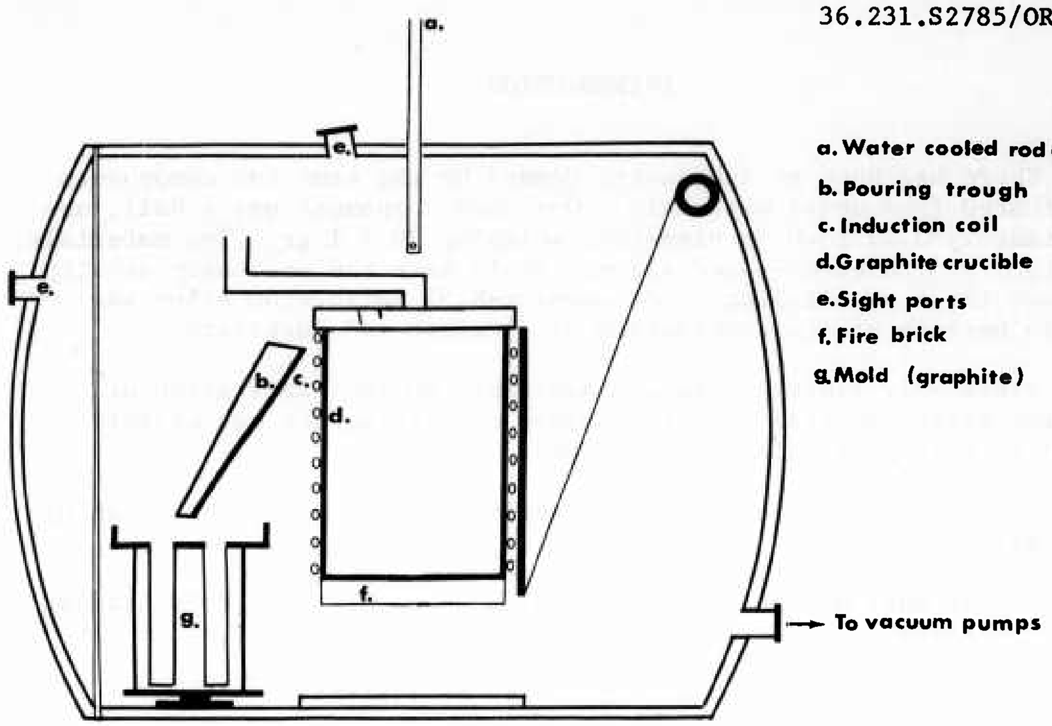

Figure 1. Schematic of 500-lb capacity Vacuum Furnace used at Frankford Arsenal

coated with a zircon wash to prevent carbon pick-up, was used as a mold material. Casting procedures for uranium are well established, and several references[1,2,3*] are available.

Heat Treatment

The bars were heated to 1650° F in a vacuum for 16 hours, and oil-quenched to room temperature. This heat treatment is necessary in order to dissolve the embrittling phases that are usually found in castings of uranium-8.5% molybdenum alloys. An oil quench is necessary to retain the high temperature, body-centered cubic phase.

Forging

A hot forging operation was required to break up and further homogenize the cast structure. The bars were heated to 1650° F in a lead pot, and forged into one inch diameter rod. A 1-ton capacity forging hammer was used. The forgings were heavily oxidized, and this oxidation layer was removed by machining. The bars were then cut into 1-ft lengths. The machined lengths were again heated to 1650° F

*See REFERENCES.

in a vacuum for 16 hours and oil-quenched to room temperature, in order to homogenize the forged structure. If this heat treatment was omitted, the bars cracked during the subsequent rolling operation.

Rolling

The 1-inch diameter bars were then cold rolled to 0.250 inch diameter through successive passes on a grooved rolling mill having a 250-ton capacity. A total of 14 grooves was used, with each groove representing approximately a 14 percent reduction of the previous area. The finished bars were 18 feet long and had a total reduction of 94 percent.

Annealing

Before further reductions were attempted, an annealing process was necessary to relieve the stresses that resulted from the rolling operation. The bars were passed through an induction coil, using the apparatus shown in Figure 2. A flow of argon was used as both a quenchant and protective atmosphere. The annealing temperature was between 1500° and 1600° F.

Swaging

The rolled bars were reduced to the final size of 0.168 inch diameter through successive passes on a small swaging machine. From the initial rolled rod to the finished swaged diameter, the material received a total reduction of 50 percent. This was not possible, however, without an intermediate anneal midway through the operation.

The choice of a proper lubricant was an important factor in this operation. Two types of graphite mixture were used. One had a lacquer base, while the other used molasses as the vehicle. While both performed adequately, the graphite in lacquer mixture was found to be more desirable because of its ease of application and removal. The finished annealed wire is shown, along with a forged bar, in Figure 3.

Mechanical Testing

Tensile tests were performed on the finished annealed wire using a Tinius Olsen testing machine modified for wire. The properties were 132,000 psi ultimate tensile strength, 130,000 psi yield strength, and 7 percent elongation.

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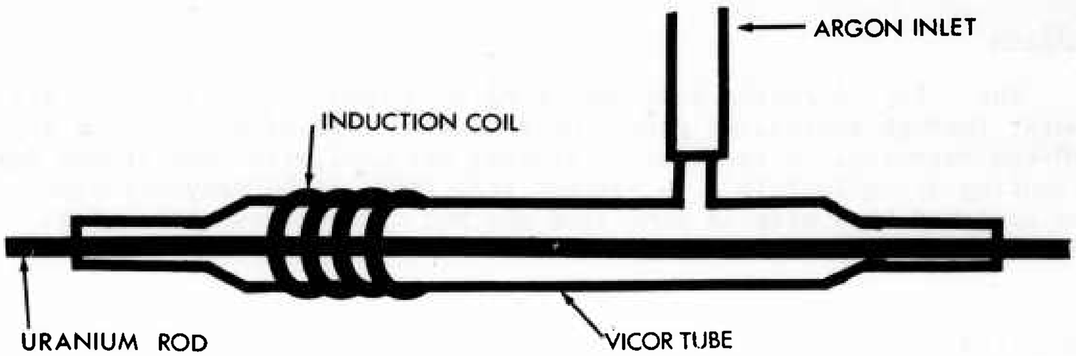

Figure 2. Schematic of Induction Unit used for Annealing Cold Worked Uranium Bars and Wire

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Figure 3. Photograph of as-forged Uranium Bar and finished Wire

Manufacture of Ball

The wire was handled in the normal fashion used for the manufacture of precision steel ball bearings. This technique is described in the Appendix. After cold heading, the product was annealed in a vacuum to prevent cracking. A cold headed ball, along with the finished product, is shown in Figure 4. A photomicrograph of the annealed cold headed ball, which has a VPH of 292, is shown in Figure 5.

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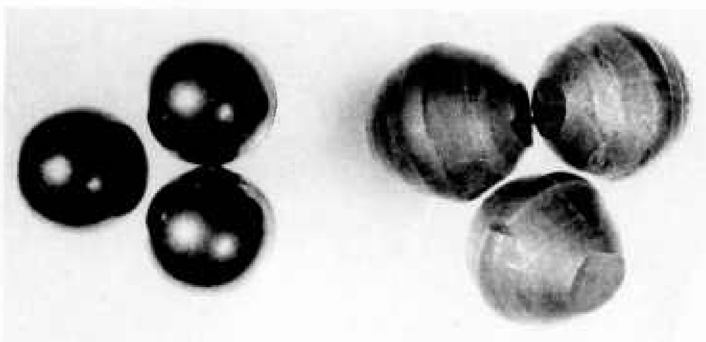
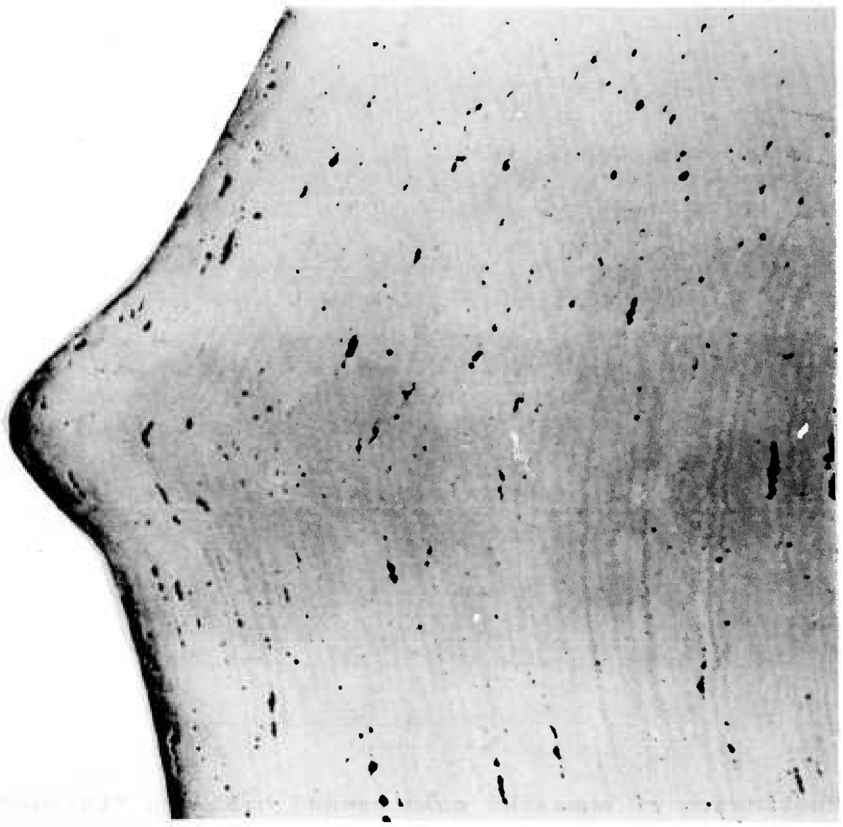


Figure 4. Photograph of annealed cold headed ball and finished product

Mag. 4X



Mag. 100X

Figure 5. Photomicrograph of Annealed Cold-headed Ball, showing the Area of Cold Work

DISCUSSION

The hot forging operation offered no significant problems. The yield strength of uranium-8.5% molybdenum alloys remains high at forging temperatures, and a high capacity hammer should be used for large sections. This alloy is more resistant to forging reductions than low alloy steel. For example, a 1-ton hammer is limited to about 2-1/2 inches diameter of uranium, while it will easily forge five inch diameter steel stock. The hammer used in this investigation proved to be adequate, but a larger one would have been more desirable.

The rolling operation was initially troublesome, as early attempts resulted in the work fracturing. The 14 percent reduction per groove proved to be too high for this alloy to absorb in one pass. Subsequent rolling was successful when two passes were used for each groove, the rolls being raised the appropriate amount to give seven percent reduction on each pass.

The heat produced in the material from the cold working operation proved to be very helpful. Although no actual data are available, it is generally accepted that the ductility of uranium alloys will be increased noticeably with small increases in temperature.[4] This increased temperature was probably the major factor contributing to the success of the rolling operation, as 94 percent reduction was obtained without an intermediate anneal.

The uranium-8.5% molybdenum alloy in a work-hardened condition will crack severely within 12 to 48 hours after the working operation. This occurrence necessitates annealing directly after cold working. The reasons for such failures are as yet unknown, and they have not been observed in unalloyed uranium.

CONCLUSIONS

1. Uranium-8.5% molybdenum alloys can be hot and cold worked easily when given proper thermal treatments.

2. The manufacture of precision balls can be accomplished using standard industrial techniques.

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2. P. S. Schaffer, "Uranium Alloy Vacuum Induction Melting," AFS Transactions, Vol 69, p 771, 1961.

3. R. V. London and R. E. Edelman, "Chill Effect on Cast Uranium-8.5 Per Cent Molybdenum Plates," Modern Castings, May 1964.

4. N. Davies, "Rolling Uranium," Sheet Metal Industries, p 654, September 1963.

APPENDIX

FEASIBILITY STUDY TO DETERMINE TECHNIQUES FOR MANUFACTURING PRODUCTION QUANTITIES OF URANIUM BALLS

Conducted by: Atlas Ball Division, SKF Industries, Inc.
For: U.S.Army, Frankford Arsenal
Contract: DA-36-038-AMC-748(A)
Date: 17 December 1963

Introduction:

The purpose of this study was to determine the mechanical and economic feasibility of manufacturing 20-grain uranium balls by conventional steel ball manufacturing methods.

Test Details:

Pressing Material - Material used was furnished by the Frankford Arsenal in the form of eight-foot rods, swaged to a diameter of 0.172 ± 0.002 inch, and annealed to a hardness of Rockwell C-23. The material composition is described as "depleted uranium containing 0.22 percent unverified assay U-235 with 8.5 percent of molybdenum added."

Pressing Mechanics - Early tests showed that the cold flow characteristics of the material, as supplied, were considerably poorer than 52100 bearing steel and slightly poorer than 440-C stainless. The material would not conform to standard ball die cavity configurations without excessive cracking and splitting. A die was constructed that would produce a headed blank of an oval shape roughly resembling a foreshortened football. The objective was to produce a shape that would require minimum cold deformation and would feed into subsequent manufacturing operations by rolling down an inclined feeding chute. These dies were installed on a standard 5/16 inch National Ball Heading Press with a carbide inserted round cutter and shearing plate.

When the press was run at the standard speed of 305 strokes per minute, reduced, but still unsatisfactory, splitting of the ball blanks was encountered. The drive mechanism on the press was altered to reduce the press speed to 190 strokes per minute, and acceptable results were achieved.

The balls were pressed to an approximate diameter of 0.247 inch. Forty-six pounds of ball blanks were pressed and stress relief annealed the same day by the Frankford Arsenal.

Pressing of standard chrome steel balls of this size would employ wire of 0.161 inch diameter. The larger size (0.172 inch diameter) was used to minimize expansive deformation requirements to reduce splitting of the balls at the pressing band. It is recommended that any future balls of this material be pressed utilizing wire slightly larger than that normally used for an equivalent ball size of 52100 material. Test observations indicated that the die life and cutter life would be substantially less than that achieved with 52100 bearing steel. The quantity of material pressed was not sufficient to permit any quantitative statement as to die and cutter life.

Rill Filing - A small ball manufacturing machine of S.K.F.design was set up in an isolated area and equipped with tooling for "Rill Filing" of the balls. The balls were round and free of pressing defects after removing 0.024 inch of diameter (size at clean-up, 0.223 inch). The balls were allowed to continue running until they reached the 20-grain weight, which was 0.205 ± 0.0005 inch. A comparison of the machine running hours per increment of stock removed shows that this process removed material from the uranium balls at a rate of 92 percent of that of 52100 bearing steel. It is felt that the errors inherent in this single test could account for an 8 percent error in these results and that, for practical purposes, one could consider the removal rates for the Rill Filing operation equivalent to 52100 steel.

The balls at the conclusion of the filing operation were 0.206 inch in diameter and had an average surface finish of 59 rms and a weight of 20.4 grains.

Tumbling - One-half of the lot of balls was self-tumbled dry for 18 hours. This reduced the average surface finish to 37 rms.

Discussion:

It was readily apparent from these tests that balls can be manufactured of the subject material by standard ball manufacturing techniques.

In order to minimize the manufacturing costs on any future volume production, we recommend that the pressing size be held at 0.232 to 0.236 inch in diameter and a wire size of 0.163 ± 0.002 inch. The wire should be furnished in coils of a minimum weight of 150 lb. The coils must be free"kinking" and tangling.

Estimated Conversion Costs for Volume Production:

A facility to utilize the economies of volume production, in an isolated atmosphere, would require a minimum production rate of 300,000 pieces per day.

Assumptions:

Volume - Minimum 300,000 pieces per day.

Material - 150-pound coils of wire 0.163 ± 0.002 inch. Material to be furnished by the government at no cost, F.O.B. conversion site. Material removed from the balls after pressing will be approximately 37 percent of finished ball weight. Scrap losses are estimated to be 10 percent. Therefore, material to be supplied must be 47 percent greater than delivery requirements.

Ball Specification - 20 ± 1 grains. Surface finish, 60 rms avg.

Packaging - Finished balls to be packaged in standard ball cartons capable of containing approximately 60 pounds of finished Uranium balls.

Shipping Terms: F.O.B. conversion site.

Estimated Sales Price for Conversion:

Based on the above assumptions, it would be reasonable to expect a supplier to convert wire into finished balls as specified for between $2.75 and $3.25 per thousand balls or per 2.82 pounds.

Recommendation:

The above estimated prices and the material weight losses could be substantially reduced if the pressing method were refined so that the balls, as pressed, would more nearly conform to spheres. It would not be unreasonable to expect that the balls could be pressed at 0.222 inch diameter instead of 0.234 inch diameter. This would reduce the weight loss of material from 37.5 percent to 27 percent, and reduce the conversion price range to $1.90 to $2.40 per thousand balls.

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FA Rpt M65-3-1, Jul 64; 14 pp incl illus.
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3. Cold Working of Uranium

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MANUFACTURE OF URANIUM-8.5% MOLYBDENUM BALLS

by R. V. London and R. E. Edelman

FA Rpt M65-3-1, Jul 64; 14 pp incl illus.
OCMS Code 5520.22.46804.03; DA Project 5S96-10-001

In an effort to meet increasing demands by the army for components fabricated from dense materials (such as an 0.20 in. diameter ball weighing 20 ± 1 gr), a study was made to find suitable material and methods of processing. Of the two materials (uranium- and tungsten-based alloys) having the necessary density, an uranium 8.5% molybdenum alloy was chosen because of its combination of strength and ductility.

The problem of fabricating a smooth wire, free from kinks and surface imperfections was undertaken at Frankford Arsenal, and the various phases of processing - casting, heat treating, forging, rolling, annealing, swaging, and testing - are described.

A feasibility study to determine techniques for manufacturing production quantities of uranium balls was undertaken by the contractor, using the cold heading technique and then grinding the rough balls to size, using standard production equipment. The methods of pressing the material, rill filing, and tumbling are described in the Appendix.

UNCLASSIFIED

1. Uranium Alloys
2. Ball Fabrication
3. Cold Working of Uranium

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Distribution Limitations:
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